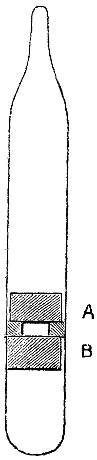
at much lower temperatures than they do at ordinary atmospheric pressure. Pellat* pointed out that the proximity of the surface of a metal to that of another metal in air, changes its electrical condition, and he attributed this to vaporization of metals, showing that even iron exerted an influence at a distance. Colson† showed that a photographic plate was affected by the vapour of certain metals, notably by zinc, cadmium, and magnesium even through porous septa. Dr. Russell‡ in some recent and very interesting experiments, was led to the conclusion that even so infusible a metal as cobalt will by vaporization, affect a photographic plate. In January, 1897, before hearing of Dr. Russell's experiments, I began some experiments with a view to ascertain whether metals, vaporized *in vacuo* near the ordinary temperature, will actually unite to form alloys. The arrangement is shown in fig. 6. A and B are two discs of metal with polished surfaces separated by a ring of glass, the whole being enclosed in a vacuous tube which could be heated in a water bath. I found that when cadmium and silver were opposed for eight days at a temperature of 50° an appreciable deposit of a tinted cadmium-silver alloy formed on the surface of the silver. Cadmium must, therefore, have passed across the interval between the discs A and B.

FIG. 6.



The results given in the present paper, reveal additional points of similarity between the behaviour of alloys and that of ordinary saline solutions. I trust, therefore, that it may be useful as a continuation of my investigation on the "Diffusion of Metals," which formed the subject of the Bakerian Lecture of 1896.

"Experimental Investigations on the Oscillations of Balances." By D. MENDELÉEFF, For. Mem. R.S. Received June 9,—Read June 9, 1898.

In the year 1893 the Central Chamber of Weights and Measures (Glavnaya Palata Mer y Vesov) was created in St. Petersburg to act as a Central Institution of the Empire for the verification of all kinds of standard measures. Having been appointed Director of the above-mentioned Institution, I was first of all occupied in

* 'Comptes Rendus,' 1882, vol. 94, p. 1247; 1896, vol. 123, p. 104; and 1898, vol. 126, p. 1338.

† *Ibid.*, 1896, vol. 123, p. 49.

‡ 'Roy. Soc. Proc.,' 1897, vol. 61, p. 424, and *ibid.*, vol. 63, p. 102, Bakerian Lecture, 1898.

making arrangements for accurate weighings, whereby some improvements have been introduced in the usual methods; a detailed description will be found in the official report on the renewal of Russian standards of measure and weight.

The results of the work show that with the balances of our Institution we are able to find the difference between two platinum-iridium kilogram weights by one single weighing with an accuracy of $\pm$ 0·02 milligram, and by a system of weighings to $\pm$ 0·002 milligram with a probable error of a few ten-thousandths of a milligram.

We have a number of such balances, but those mostly used were constructed by the well-known balance makers of Vienna, Ruprecht and Nemetz; some important improvements have been made upon these balances, especially in the direction of minimising the influence of the observer.

Having obtained such results in accurate weighings, I have used them, not only in the comparison of standards of weight, but also in an experimental research on the oscillations of a balance, hoping to collect some material, not only for an investigation of balances of different systems and constructions in general, and of the friction of the knife-edges, but especially to find the action of gravity and moment of inertia on such a pendulum as is represented by an accurate balance.

If we consider the time of one oscillation (from 30 to 60 seconds), we find that our balances correspond to synchronous mathematical pendulums of a length equal to 1000—3000 metres. The investigations in this direction are not yet completed, but one part of the results obtained is now in print, and I would like to communicate an abstract to the Fellows of the Royal Society.

Before going into the matter, I must explain that the many hundreds of observations of the times of oscillation and the changes in the scale-reading have been made by my friends and assistants, especially F. P. Zavadsky, V. D. Sapogenikoff, and also by Messrs. Dobrokhotoff, K. Egoroff, Miller, and Misses Ozarovskaya and Endymionova. Their active co-operation has greatly contributed to the success of the experiments, and I am much indebted to them for verifying the numerous calculations which this research involves.

In the investigations mentioned, the following data were observed:—

1. The readings of the scale, l_n, were observed through a telescope after reflection from a mirror attached to the beam of the balance, l_1 is the first reading. One division of the scale corresponds in the different balances to an angle of from 0·5 to 4 minutes. The readings were taken by estimation to 0·05 division, which agrees nearly with the probable error in l.

From every set of four to five readings the position of equilibrium L_n was deduced, and the amplitudes r_n, by taking the differences between l_n and L_n. The difference between r_n and r_{n+1} is called in what follows the decrement D_n.

2. The time of the passage through the position of equilibrium, T_n, was determined partly by the use of a chronographic watch, partly by Marey's cylindrical chronograph, reductions having been made to true astronomical mean time by comparisons with our standard clock (Hohwü 31) controlled by signals from the Pulkova Astronomical Observatory.

From the observed T_n was deduced the mean duration (in seconds of mean time) of one oscillation, *i.e.*, from l_n to l_{n+1}.

3. k, the number of milligrams corresponding to one division of the scale.

4. e, the weight in milligrams of a litre of air inside the balance case, according to readings of the thermometer ($\pm 0{\cdot}003^\circ$), barometer and Assman's psychrometer.

5. p, the weight of the load on each pan expressed in grams.

6. P, the weight of the whole moving mass of the balance and the load in grams.

7. v, the volume of the load in millilitres. The same has an influence on t_n and D_n, and we have examined the change of D_n and t_n.

I. *The Variation of* D *and* t *depending on the value of one oscillation,* $R_n = l_n - l_{n+1}$, *or amplitude,* $r_n = (L_n - l_n)(-1)^n$.*

The duration of one oscillation, all other conditions being constant in all six examined balances without exception *decreases with decreasing* oscillations *or amplitudes.* These variations are not only many times greater than the errors of the readings, but many hundred times surpass the corrections of the time of one oscillation, as deduced from the usual formula for the reduction of the oscillations of a pendulum to infinitely small amplitudes. The decrease of the time of one oscillation in the most simple manner can be expressed in first approximation by the formula

$$t_n = t_0\beta^{-n} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1).$$

Therefore $$T_n = Q - U\beta^{-n},$$

where $$U = \frac{t_0}{\text{log. nat. } \beta^n}$$

and $$Q = T_0 - U.$$

* r_n is very nearly equal to $\frac{1}{2}$R, but I prefer to give D and t in relation to r_n, because by this method the small errors in L_n disappear.

More clearly visible is the *decrease of* D *with decreasing amplitude* r_n, and it is sufficient to observe four readings. The experimental law of the decrease of D by first approximation can be represented by the formula

$$D_n = d+\alpha r_n,$$

where d is the limit of the decrement in the case of infinitely small amplitudes, and α a constant coefficient, which in all examined balances varied between 0·0010 and 0·0002. Observations relating to t_n and D_n have been made in a very great number, and all of them confirm the above given result.*

Therefore
$$r_n = \frac{r_0}{\alpha r_0 \,.\, \frac{d^n-1}{d-1}+d^n},$$

or
$$\frac{1}{r_n} = \mathrm{K}d^n - \mathrm{N},$$

where
$$\mathrm{N} = \frac{\alpha}{d-1},$$

and
$$\mathrm{K} = \mathrm{N}+\frac{1}{r_0}.$$

Similar facts about t and D have been shortly mentioned before,† but little notice of them has been taken. But in our very numerous observations these facts stand out so clearly and beyond doubt, that also in the ordinary simple pendulums we must suppose the existence of similar deviations which only by their smallness have escaped the attention of the observers. I have commenced the investigation of a simple pendulum in this direction.

As D and t are varying with the amplitude r_n, in what follows D and t will be given for the case when $r = 15$ divisions, using the signs D_{15} and t_{15}.

II. *Variation of* D_{15} *and* t_{15} *with varying load.*

The time t_{15} in all balances decreases with decreasing load and k.

(*a*) For one kind of balances very quickly, as, for instance, Ruprecht's balance:—

	1.	2.	3.	4.
p	0 grms.	105 grms.	430 grms.	563 grms.
P	1234 ,,	1440 ,,	2099 ,,	3358 ,,
D_{15}	1·0136	1·0180	1·0217	1·0244
t_{15}	27·3 secs.	28·5 secs.	38·3 secs.	48·2 secs.

* For details see the above mentioned Official Report.

† *Cf.* O. E. Meyer, 1871, Mercadier, 1876, T. Thiessen, 1886, and others.

(*b*) For other balances considerably slower, as for the balance of Nemetz :—

P	1147 grms.	1359 grms.	2213 grms.	3442 grms.
k	0·0192 mgs.	0·0234 mgs.	0·0481 mgs.	0·0670 mgs.
D_{15}......	1·0321	1·0392	1·0337	1·0313
t_{15}	30·5 secs.	32·8 secs.	33·3 secs.	33·7 secs.

The decrement D_{15} in some balances with increasing load (*a*) increases as with the above-mentioned balance of Ruprecht, or (*b*) decreases as with a balance of Collot designed to carry a load of 40 kilograms on each pan :—

$\frac{p \text{ grm.}}{409·5 \text{ grm.}}$ =	0.	1.	2.	4.	8.
P ..	29,879 grm.	38,069 grm.	46,259 grm.	62,640 grm.	95·402 grm.
D_{15}..	1·0459	1·0316	1·0259	1·0172	1·0103
t_{15} ..	55·9 secs.	53·0 secs.	49·3 secs.	43·5 secs.	35·9 secs.

In this case the variation of D in relation to p corresponds in first approximation to a hyperbola with an asymptote = 1 or (*c*), a combination of the preceding (*a*) and (*b*).

III. *Variation of* D_{15} *and* t_{15} *with the Variation of the Sensibility of a Balance* $1/k$.

If k increases, all other conditions being the same, then D_{15} and t_{15} decrease as with the balance of Nemetz. (P = 2213 grams.)

k	0·034 mgrms.	0·055 mgrms.
t_{15}	37·3 secs.	30·6 secs.
D_{15}	1·0363	1·0286

IV. *Variation of the Time of one Oscillation depending upon the Friction of the Knife-edges (Prisms) against the three Planes.*

When the pans and the movable parts used for suspending them are removed and the balance beam alone is oscillating, there is friction only at the middle knife-edge, and the time of one oscillation is shortened, as with the above mentioned balances of Collot and Ruprecht; for the latter we have found—

	With pans but without any load.	Beam only.
P	1231 grms.	678 grms.
k	0·0310 mgrms.	0·0290 mgrms.
t_{15}	27·3 secs.	15·0 secs.
D_{15}	1·013	1·007

If in the balance of Nemetz the pans are suspended from the beam,

and we put in the place of the middle agate plane (the knife-edges being of flint) planes of the same size but of different material, we find a change in the time of the oscillation; from thirty-two oscillations in each case we have obtained the following mean results (P = 2178 grams) :—

Material of the middle plane.	Time of one oscillation, t_{15}.	D_{15}.	k.
Hard steel	33·3 secs.	1·034	0·043
Agate	32·7 „	1·031	0·044
Copper	25·4 „	1·065	0·071
Horn	18·2 „	1·115	0·093

That is to say, the time of one oscillation in the last case is one-half of that when an agate plane is used, although the load and the position of the centre of gravity were the same in both cases.

Therefore the experiment shows a great dependence of the time of one oscillation decrement and of the sensibility from the friction of the knife-ed ;es, although usually it is assumed that t and k do not directly dei end upon the friction. Further experiments are going on, espec' ly as regards the changes found in the value of the decremen

V. *V iation of t and* D *depending upon the Dimensions of the Horizontal Section of the Load.*

If we ı ut on the pans of the Ruprecht's balance two platinum-iridium pounds (Russian) (cylinders of which the height and diameter are equal and the weight 409·5 grams), we find k = 0·033 milligram, t about 4·4 secs., and D about 1·0175; replacing these weights by two plat·s of 914 square cm. section (of the same weight 409·5 grams), we find t about 39·7 secs., and D about 1·0240.

VI. *Variation of t and* D *with the Variation of the Volume of the Load.*

VII. *Influence of the Variation of the Density of the Air e*, and

VIII. *The Inner Friction of the Gas in which the Oscillations are going on.*

The experiments will be continued and extended, and I hope to obtain results which will throw more light on the little explored regions of the oscillation of a balance considered as a physical pendulum of peculiar properties.

Some results will probably be applicable to the ordinary physical pendulum.

But, for the moment, I would not like to make any theoretical generalisations.

* *Vide* Bessel and F. Baily, 1832, "Pendulum Experiments."